A Geomorphic Enhancement for Flood Control

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Abstract

A feasibility study of flood damage reduction measures for the Town of Elkton in Cecil County, Maryland is being performed due to numerous reports of flooding in the downtown area and in Eder Park. The flooding is being caused by Big Elk Creek. Floods as frequent as the annual event were found to impact developed properties and baseball fields in Eder Park. A cost-sharing agreement has been signed with the Town of Elkton to evaluate potential solutions to their flooding problems. Many solutions, from levees to upstream impoundment basins and high-flow overbank channels, have been proposed to resolve the situation. These alternatives proved to be infeasible for various reasons. In light of this, a new alternative involving natural stream restoration techniques has been proposed. The Town of Elkton has indicated that they are interested in pursuing this alternative.

This latest option, which combines stream channel improvements with flood proofing (grading/landscaping) of structures on the left bank of the stream, acts to resolve two distinct problems with Big Elk Creek, lack of aquatic habitat and an inefficient channel geometry to carry stream flows. The proposed stream channel restoration measures, would provide the proper dimension, pattern, and profile of the stream channel to improve conveyance and eliminate sediment buildup. In-stream rock structures will provide bed and bank stability, and control erosion of the channel's banks. A meander-bend in the Eder Park area of the stream will be relocated to its historic location to provide proper slope and curvature to the channel. The remaining portion of the bend will be used as an oxbow lake and will be modified to improve potential fish habitat.

After making all of these changes, the stream channel improvements will reduce the annual flood's water surface elevation in excess of one foot due to the improved conveyance. When the channel improvements are combined with flood-proofing, the protection for some buildings is as high as the 75-year flood. In addition, the elimination

of the meander-bend combined with the other improvements halts Big Elk Creek's propagation towards developed properties on the left bank.

The Baltimore District was able to convince the Elkton Town Council that the consequences of taking no action would be serious. The stream would eventually erode the left bank to the point that developed properties would be in jeopardy of being undermined. In addition, future flood events would worsen, as sediment deposition would reduce overall conveyance and stream velocities resulting in higher flood stages.

In summary, an alternative has been developed for this flood protection study that produced benefits for reducing frequent flood stages and damages as well as elimination of potential environmental hazards at the same time by realigning the channel at the meander bend to direct flows away from the developed properties on the left bank.

Introduction

The Elkton Local Flood Protection Project provided a unique case where non-structural measures, such as channel improvements and floodproofing, may need to be substituted for structural flood protection measures to address specific local interests and environmental concerns. This report illustrates how geomorphic enhancements can provide flood damage reduction for areas where frequent flooding occurs, where funding for flood control is tight, and where specific interests hamper the implementation of traditional structural methods such as levees and impoundment basins. The Elkton Local Flood Protection Project was found to fit this mold after extensive investigations of alternatives.

Due to the relatively low elevations of the development along the banks of Big Elk Creek in Elkton, frequent flooding occurs. In addition, flood protection benefits are very pronounced for routine flooding events at the 1, 2, and 5-year return periods. Also, pronounced sedimentation and erosion problems are present throughout Big Elk Creek. A proposed levee alternative would have provided 100-year flood protection, but it was found to be in conflict with local interest viewpoints as well as being unjustfied economically due to its high cost.

Therefore a combined stream channel restoration and floodproofing alternative was considered and approved by the Elkton Town Council. All local interest groups were excited about the benefits and low cost of the alternative. The stream channel restoration option included channel cross section modifications, the straightening of an oxbow bend near Eder Park, and the installation of rock vane structures. These modifications improved conveyance and sediment transport while allowing for a more symmetrical flow regime that would reduce erosion. This alternative would allow for a water surface reduction of 1.2 feet at Eder Park for an annual flood event. The alternative would also address the stream channel migration at the downstream bend in the oxbow that would undermine and destroy the Holly Hill Shopping Center area on the left bank of the creek, if erosion of the stream bank were to continue in the future. In addition, floodproofing of structures on the left bank would provide protection up to a 75-year flood for some structures. The remaining oxbow area would become a wetland area for fish habitat.

The Elkton, MD Local Flood Protection Project

Due to reports of frequent and severe riverine flooding associated with Big Elk Creek by the Town of Elkton and Eder Park, the Baltimore District of the U.S. Army Corps of Engineers was called upon to provide a solution to protect the town from the floods.

Big Elk Creek Drainage Basin

Elkton lies between Big Elk Creek and Little Elk Creek. These streams delineate parts of the eastern, southern, and western boundaries of the town (Reference 1). Big Elk Creek and Little Elk Creek flow from Oxford, PA about 20 miles to Elkton where they merge to form a 15-mile tidal reach called the Elk River and drain into the Upper Chesapeake Bay.

The town of Elkton is located in a transitional area between the Appalachian hills of the Piedmont Plateau and the coastal plain that bounds the Atlantic Ocean. The stream characteristics transition from the deep, narrow streams of the Piedmont upstream to the wider, shallow tidal-influenced streams downstream.

Flooding History in Elkton

Fluvial flooding problems are very common with Big Elk Creek (Reference 1). Major flooding events occur due to hurricanes, thunderstorms, and other mid-latitude storm that are swept across the area due to the jet stream. Most recently, a late-winter rainstorm in February 2003 produced flooding and ice jams due to severe cold weather during most of the winter (Figure 1). The Delaware Avenue Bridge was damaged by the ice jams to the point that repair crews were needed (Figure 2).

Elkton Local Flood Protection Project area

Elkton is located in the northeastern part of Cecil County, MD just 17 miles southwest of Wilmington, DE along the Interstate 95 corridor and along the Maryland-Delaware state line (Reference 7, Figure 3). The town is mainly located along Big Elk Creek and Little Elk Creek. The study area runs along Big Elk Creek between the Delaware Avenue bridge and US. Route 40 bridge, with the emphasis of the study in Eder Park and the most adversely affected nearby residential and commercial areas. This area of concern corresponds to HEC-RAS Cross Sections 1.49 and 1.60 which cover the areas from the former Valu-Food grocery store to Eder Park. These places are located about 800 to 1300 upstream of the Bridge Street bridge.

Hydrologic Analysis

The hydrologic analysis was performed when the levee alternatives were being considered for the project. Flood frequency analyses were performed to estimate flow rates for the various return periods at Elk Mills and Elkton along Big Elk Creek. Since there was a gage at the Elk Mills site of drainage area 52.5 square miles, the Elk Mills flood frequency analysis was performed using the HEC-FFA program (Reference 2) using a period of 67 years from 1932-1998. The generalized skew coefficient of 0.5 was retrieved from the USACE Tropical Storm Agnes hydrological study (Reference 3). The FFA adopted skew for the distribution was +0.20.

There is no stream gage at Elkton along Big Elk Creek. However, the drainage area is known to be 66 square miles. Therefore, an equation from Ven Te Chow's Handbook of Applied Hydrology (Reference 4) was used to transpose flow data from the Elk Mills stream gage location downstream to Elkton:

$$Q_{upstream}/Q_{downstream} = (DA_{upstream}/DA_{downstream})^{exponent}$$

Usually, the exponent carries a value between 0.5 and 1.0. However, due to the fact the Big Elk Creek watershed is narrow, a value of 1.4 produced flowrates that correlate well to observed Elkton flows.

The following table summarizes the flow values that were used for the study based on an analysis from 1999 using HEC-FFA (Figure 4).

Return Period	Flow Rate (cfs)
1-year	1650
2-year	3600
5-year	6000
10-year	7900
25-year	10800
50-year	13200
100-year	16000
200-year	19000
500-year	24000

The Process of Considering Alternatives for the Project

Initially, the goal of the study was to provide protection from the 100-year floodto the Town of Elkton. Levees on the right bank, the left bank, and both banks were proposed. The right bank levee was proposed to protect structures in Downtown Elkton. However, it was found that the costs for the levee outweighed the benefits of flood protection from the levee. Also, the Eder Park Association, which owns some of the land where the proposed levee was to be constructed, decided that their park lands should not be used for flood control projects. This stance taken by the Eder Park Association eliminated the possibility of pursuing the alternative with levees on both the right and left banks of the creek, since this alternative would be more expensive and the Eder Park Association objected to the alternative as well. A left bank only levee was considered unacceptable because it would not provide any flood damage reduction for properties in Downtown Elkton on the right bank of the creek.

A water control structure at a Conrail railroad trestle downstream of Maryland State Route 279 was proposed. This impoundment basin was designed to pond water upstream of the railroad and attenuate the flow downstream to lower the water surface elevation. The water control structure attenuated the 1-year rainfall event 20% but produced adverse upstream impacts for storm events greater than a 2-year event. These upstream impacts made the water control structure alternative unacceptable.

With all structural flood control solutions eliminated, flood proofing was combined with a non-structural geomorphic alternative. This alternative involved restoration of stream channel geometry to a pre-development condition. Specific rock-vane structures such as J-Hooks (Figure 5) and cross-vanes (Figure 6) would be used to maintain flow velocity distribution to prevent erosion and sediment deposition.

Field visits determined that major sediment deposits were present downstream of bridges due to low flow velocities. In addition to the Delaware Avenue Bridge damages by the ice flows, erosion was found to be undermining an area on the left bank of the creek near the Holly Hill shopping area. Channel geometry was found to be inefficiently conveying water due to sharp bends near the oxbow, irregular cross-sectional geometry, and frequent occurrences of adverse slope.

A hydraulic analysis of the geomorphic / stream channel restoration was performed and will be described in the next section. The study resulted in water surface decreases in excess of 1 foot in the important Eder Park area for an annual event with noticeable benefits up to the 5-year flood (Table 1).

Hydraulic Analysis

The hydraulic analysis for the geomorphic enhancements using the HEC-RAS computer model involved modification of stream channel cross-sectional geometry between cross-sections 1.09 and 2.28, from the Delaware Avenue bridge to the Bridge St. bridge. In addition the oxbow bend was translated from the deep bend to a former location (Figures 7 and 8) that is thought to be the original stream channel location prior to the urbanization of Elkton. The old oxbow channel will be adapted to serve as a wetland area for fish habitat. The modified conditions model will be hereby referred to as "proposed", while the existing conditions model showing the current oxbow and cross sectional geometry will be referred to as "existing".

The existing conditions model was verified and modified to make sure the existing conditions observed in the field corresponded to the model conditions. Therefore, the model was labeled as "modified existing" even though it will be referred to as "existing" in this report. The proposed conditions model was developed with all changes made. A table was then printed out comparing and contrasting the results from the two models.

The tailwater condition used in these models was assumed to be at a low flow level at a location well downstream of the project area. Since the normal depth considering a slope of 0.00036 was higher than Mean Higher High Water for all return periods (Reference 5), the normal depth was used as a downstream boundary condition. A subcritical flow regime was assumed for the Big Elk Creek reach analyzed in both the existing and proposed conditions models.

In the oxbow bend area, as the stream channel was straightened out, the Manning's n values for cross sections between 1.89 and 1.60 was reduced to 0.04 from 0.055 (Reference 6). The contraction/expansion coefficients were also reduced to 0.1/0.3

from 0.3/0.5 (Reference 6). Sediment buildups were removed between cross sections 1.34 and 1.09. New channel geometry was developed according to Figure 9 (Figure 9). The adverse slope along the oxbow was eliminated. These changes allowed for many conveyance improvements.

The enclosed table shows existing and proposed water surface elevations, channel velocities, and top widths to illustrate the benefits in the key areas of this project (Table 1). These results illustrate a reduction in the floodplains for the frequent flood events and a significant flood damage savings for Elkton.

Conclusions

After all issues have been considered, the Town of Elkton has stressed that flood relief is needed and acknowledged that parts of the town may be damaged by stream channel migration if nothing is done. As the expensive and unaesthetic structural alternatives were deemed infeasible by the Town, individual public interests, and the Corps, the geomorphic stream channel enhancements and floodproofing were advanced for further consideration. Despite the fact that the geomorphic enhancements and floodproofing will not provide 100-year flood protection, significant flood stage and damage reductions for frequent flood events were found to be possible at about half the cost of a levee. No negative upstream impacts were realized with this alternative, as was the case with the impoundment basin. In addition, the stream channel improvements and floodproofing for the entire Town of Elkton, in that it provides flood damage reduction for properties on both the left and right banks of the creek. The alternative table (Table 1) illustrates general results of the investigation of the alternatives.

References

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7. Mapquest.com, Inc. (2003), *Vicinity Map Of Elkton, MD. Internet Web Page at* http://www.mapquest.com/maps/map.adp?country=US&addtohistory=&address=&city=Elkton&state=MD&zipcode=&homesubmit=Get+Map.

Figure 1

Figure 2

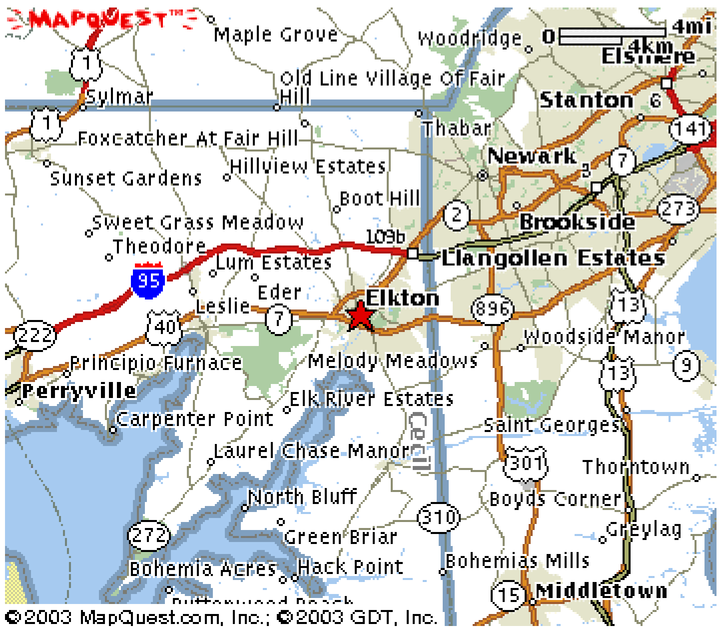
MAPQUEST
Maple Grove
Woodridge
0
4mi
4km
Elsmere
Sylmar
Old Line Village Of Fair Hill
Stanton
Thabar
Foxcatcher At Fair Hill
Newark
Hillview Estates
Sunset Gardens
Boot Hill
Brookside
Sweet Grass Meadow
109b
Theodore
Llangollen Estates
Lum Estates
Eder
Elkton
Leslie
Woodside Manor
Principio Furnace
Melody Meadows
Perryville
Elk River Estates
Carpenter Point
Saint Georges
Cecil
Laurel Chase Manor
Thorntown
North Bluff
Boyds Corner
Greylag
Green Briar
Bohemia Acres
Hack Point
Bohemia Mills
Middletown
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Figure 3

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 ************************************
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 *              FFA                 *      *
*
 *     FLOOD FREQUENCY ANALYSIS     *      *   U.S. ARMY CORPS OF
ENGINEERS    *
 *     PROGRAM DATE:  MAY 1992      *      * THE HYDROLOGIC ENGINEERING
CENTER *
 *          VERSION:  3.0           *      *         609 SECOND STREET
*
 *     RUN  DATE   AND   TIME:      *      *      DAVIS, CALIFORNIA
95616      *
 *        29 NOV 99    08:34:51     *      *          (916) 756-1104
*
 *                                  *      *
*
 ************************************
*************************************



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 OUTPUT FILE NAME: elktnffa.out




 **TITLE RECORD(S)**
 TT    Annual Series at Elkton-  Peak Flow for Big Elk Creek in cfs
 TT    Estimated Flow, DA = 66 square miles
 TT

 **GENERALIZED SKEW**
      ISTN   GGMSE    SKEW
 GS           .200     .45

 **HP PLOT **
      HP PLOT FILE                  IHPCV  KLIMIT    IPER    BAREA
 HP   ELKTNFFA.PCL                      1       0       0   66 SQ MI

      SELECTED CURVES ON HPPLOT
           EXPECTED PROBABILITY CURVE
           CONFIDENCE LIMITS

 HP  BIG ELK CREEK AT ELKTON
 HP  ESTIMATED ANNUAL SERIES

 **SYSTEMATIC EVENTS**
      67 EVENTS TO BE ANALYZED

 **END OF INPUT DATA**
 ED ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
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ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ FINAL RESULTS ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ

-PLOTTING POSITIONS-

EVENTS ANALYZED				ORDERED EVENTS			
			FLOW		WATER	FLOW	WEIBULL
MON	DAY	YEAR	CFS	RANK	YEAR	CFS	PLOT POS
7	5	1937	13469.	1	1937	13469.	1.47
6	22	1972	11080.	2	1972	11080.	2.94
8	23	1933	9568.	3	1933	9568.	4.41
7	23	1946	8996.	4	1946	8996.	5.88
1	19	1996	8933.	5	1996	8933.	7.35
9	12	1960	7853.	6	1960	7853.	8.82
8	10	1967	7776.	7	1967	7776.	10.29
9	18	1945	7662.	8	1945	7662.	11.76
8	14	1955	7446.	9	1955	7446.	13.24
7	2	1941	7217.	10	1941	7217.	14.71
2	12	1985	6874.	11	1985	6874.	16.18
7	7	1947	6633.	12	1947	6633.	17.65
1	28	1994	6633.	13	1994	6633.	19.12
1	26	1978	6506.	14	1978	6506.	20.59
10	19	1996	6493.	15	1997	6493.	22.06
7	5	1989	6391.	16	1989	6391.	23.53
7	9	1935	5997.	17	1935	5997.	25.00
7	14	1975	5769.	18	1975	5769.	26.47
1	24	1979	5400.	19	1979	5400.	27.94
5	19	1988	5311.	20	1988	5311.	29.41
2	13	1971	5121.	21	1971	5121.	30.88
12	11	1992	5057.	22	1993	5057.	32.35
2	13	1966	4689.	23	1966	4689.	33.82
9	3	1959	4346.	24	1959	4346.	35.29
8	3	1950	4320.	25	1950	4320.	36.76
8	13	1942	4295.	26	1942	4295.	38.24
12	21	1951	4168.	27	1952	4168.	39.71
1	3	1936	4066.	28	1936	4066.	41.18
1	20	1995	3926.	29	1995	3926.	42.65
1	9	1964	3850.	30	1964	3850.	44.12
6	15	1932	3837.	31	1932	3837.	45.59
11	2	1956	3659.	32	1957	3659.	47.06
5	12	1943	3634.	33	1943	3634.	48.53
11	22	1952	3482.	34	1953	3482.	50.00
3	15	1940	3431.	35	1940	3431.	51.47
4	2	1970	3355.	36	1970	3355.	52.94
3	3	1934	3329.	37	1934	3329.	54.41
8	19	1939	3329.	38	1939	3329.	55.88
11	25	1950	3329.	39	1951	3329.	57.35
1	25	1958	3291.	40	1958	3291.	58.82
9	13	1944	3024.	41	1944	3024.	60.29
10	23	1937	2935.	42	1938	2935.	61.76
3	12	1962	2770.	43	1962	2770.	63.24
12	15	1986	2770.	44	1987	2770.	64.71
2	14	1948	2694.	45	1948	2694.	66.18
12	21	1973	2592.	46	1974	2592.	67.65
8	8	1981	2579.	47	1981	2579.	69.12

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°   2   8  1965     2567.  ³    48   1965      2567.    70.59  °
°   7   4  1973     2554.  ³    49   1973      2554.    72.06  °
°   5  29  1990     2554.  ³    50   1990      2554.    73.53  °
°   1   4  1982     2211.  ³    51   1982      2211.    75.00  °
°   8   5  1949     2186.  ³    52   1949      2186.    76.47  °
°   3  22  1977     2122.  ³    53   1977      2122.    77.94  °
°   5  23  1983     2122.  ³    54   1983      2122.    79.41  °
°   3   6  1963     2058.  ³    55   1963      2058.    80.88  °
°   1   1  1961     2046.  ³    56   1961      2046.    82.35  °
°   1  14  1968     1995.  ³    57   1968      1995.    83.82  °
°   1  30  1956     1957.  ³    58   1956      1957.    85.29  °
°   1  27  1976     1944.  ³    59   1976      1944.    86.76  °
°  12  22  1983     1881.  ³    60   1984      1881.    88.24  °
°   1  23  1998     1753.  ³    61   1998      1753.    89.71  °
°   1  12  1991     1728.  ³    62   1991      1728.    91.18  °
°   3  27  1992     1715.  ³    63   1992      1715.    92.65  °
°  12  14  1953     1703.  ³    64   1954      1703.    94.12  °
°   7  28  1969     1334.  ³    65   1969      1334.    95.59  °
°   1  26  1986     1118.  ³    66   1986      1118.    97.06  °
°   3  21  1980     1084.  ³    67   1980      1084.    98.53  °
ÈÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÏÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍ¼


-OUTLIER TESTS  -
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LOW OUTLIER TEST
ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ


BASED ON  67 EVENTS, 10 PERCENT OUTLIER TEST VALUE K(N) = 2.877

       0 LOW OUTLIER(S) IDENTIFIED BELOW TEST VALUE OF    697.7


ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ
HIGH OUTLIER TEST
ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ


BASED ON  67 EVENTS, 10 PERCENT OUTLIER TEST VALUE K(N) = 2.877

      0 HIGH OUTLIER(S) IDENTIFIED ABOVE TEST VALUE OF   19193.
ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ


-SKEW WEIGHTING -
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BASED ON  67 EVENTS, MEAN-SQUARE ERROR OF STATION SKEW =   .083
DEFAULT OR INPUT MEAN-SQUARE ERROR OF GENERALIZED SKEW =   .200
ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ



FINAL RESULTS

-FREQUENCY CURVE-      □□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□
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COMPUTED CURVE FLOW IN CFS	EXPECTED PROBABILITY FLOW IN CFS	PERCENT CHANCE EXCEEDANCE	CONFIDENCE LIMITS .05 FLOW IN CFS	CONFIDENCE LIMITS .95 FLOW IN CFS
22100.	24100.	.2	30600.	17200.
18000.	19200.	.5	24100.	14300.
15200.	16000.	1.0	19900.	12300.
12700.	13200.	2.0	16200.	10500.
9740.	9970.	5.0	12000.	8270.
7740.	7850.	10.0	9230.	6700.
5900.	5950.	20.0	6830.	5200.
3590.	3590.	50.0	4030.	3190.
2240.	2230.	80.0	2550.	1940.
1770.	1750.	90.0	2040.	1490.
1470.	1440.	95.0	1720.	1210.
1040.	1010.	99.0	1260.	818.

SYSTEMATIC STATISTICS

LOG TRANSFORM: FLOW, CFS		NUMBER OF EVENTS	
MEAN	3.5634	HISTORIC EVENTS	0
STANDARD DEV	.2502	HIGH OUTLIERS	0
COMPUTED SKEW	.0814	LOW OUTLIERS	0
REGIONAL SKEW	.4500	ZERO OR MISSING	0
ADOPTED SKEW	.2000	SYSTEMATIC EVENTS	67

HP PLOT WRITTEN TO THE FILE: ELKTNFFA.PCL

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++++++++++++++++++++++++
+ END OF RUN           +
+ NORMAL STOP IN FFA   +
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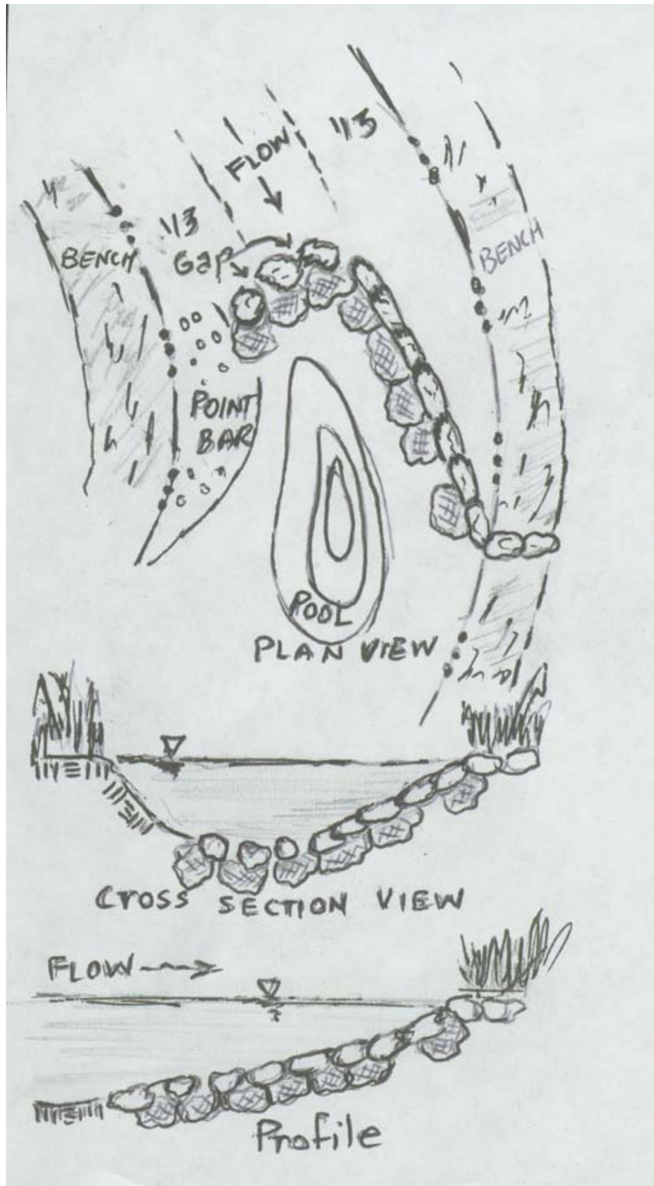
Figure 4


FLOW
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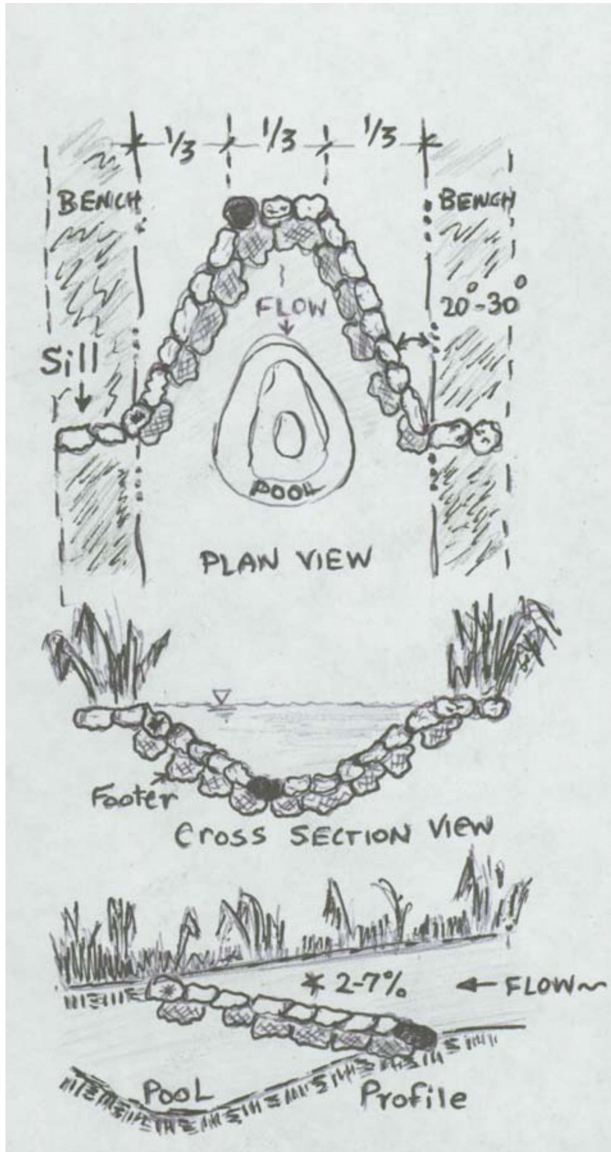
1/3
BENCH
Gap
BENCH
POINT BAR
POOL
PLAN VIEW
CROSS SECTION VIEW
FLOW
Profile

Figure 5



1/3
1/3
1/3
BENCH
BENCH
FLOW
20°-30°
Sill
POOL
PLAN VIEW
Footer
Cross SECTION VIEW
2-7%
FLOW
PooL
Profile

Figure 6

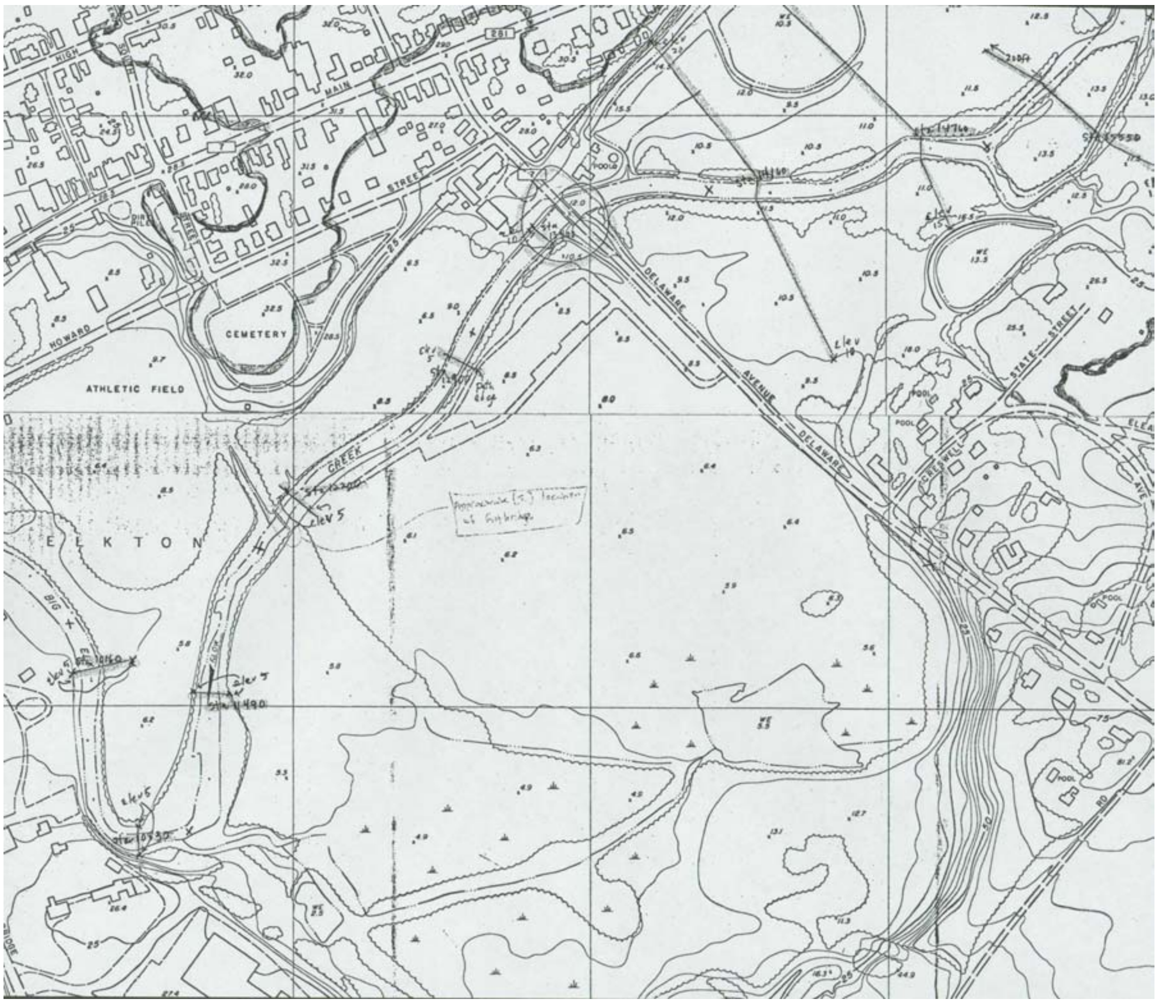


Figure 7

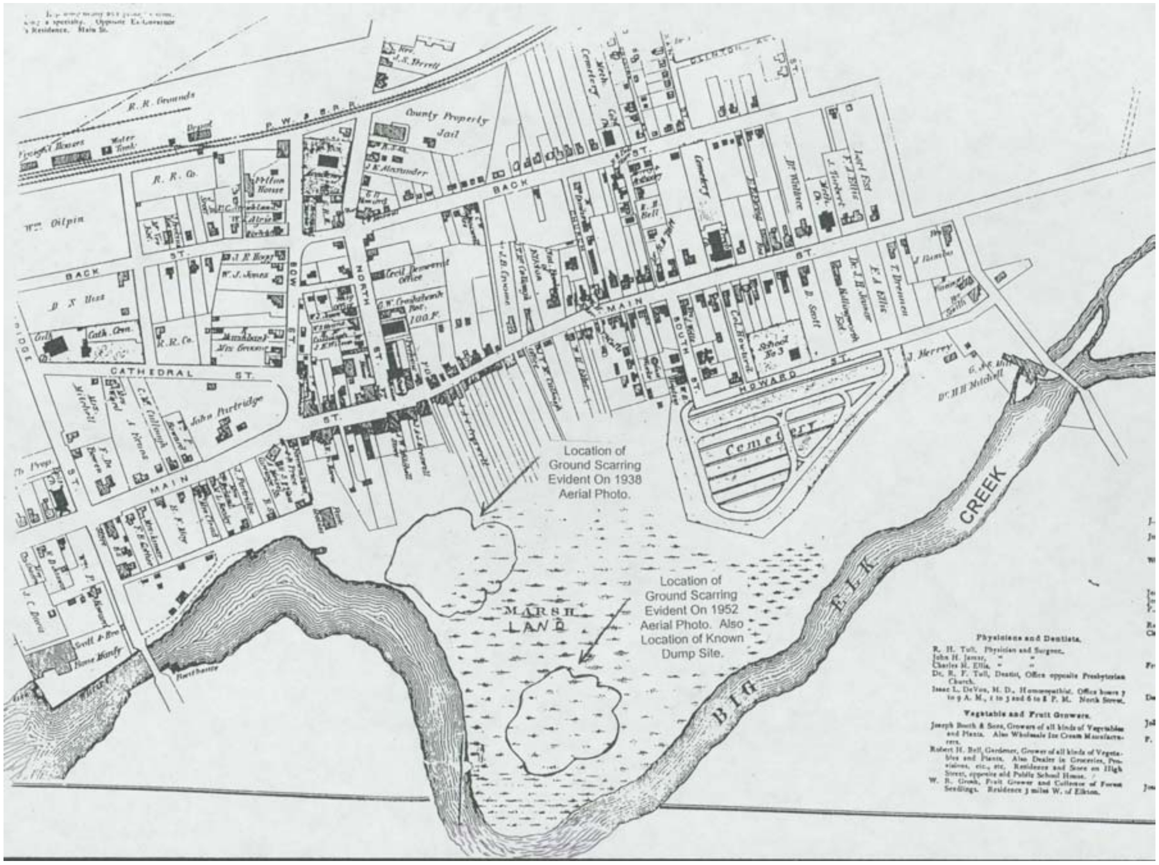

Location of
Ground Scarring
Evident On 1938
Aerial Photo.
Location of
Ground Scarring
Evident On 1952
Aerial Photo. Also
Location of Known
Dump Site.
MARSH
LAND
BIG ELK CREEK
Cemetery
County Property
Jail
CATHEDRAL ST.
MAIN
BACK
NORTH ST.
HOWARD ST.
Physicians and Dentists.
Vegetable and Fruit Growers.

Figure 8

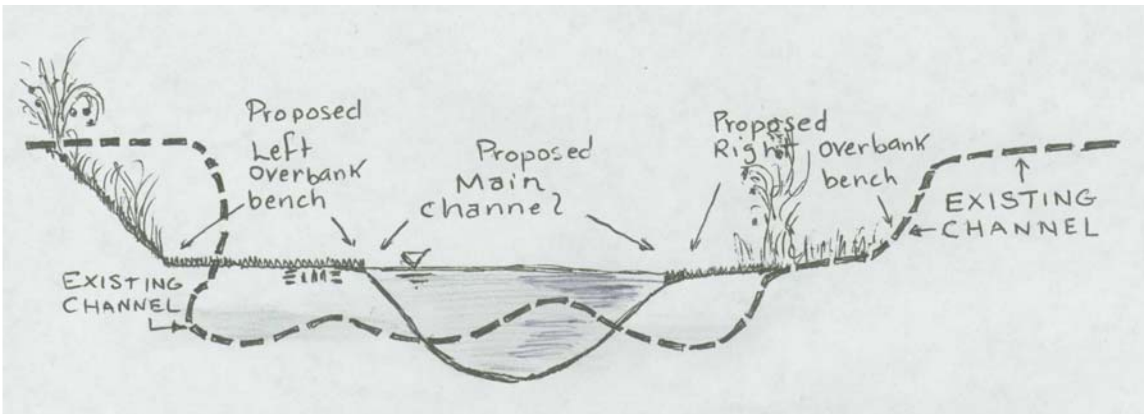

Proposed
Left
overbank
bench
Proposed
Main
channel
Proposed
Right
overbank
bench
EXISTING
CHANNEL
EXISTING
CHANNEL

Figure 9

Table 1: Flood Protection Benefits from Geomorphic Enhancements

XS 1.49	Storm	WSEL (ft, NGVD-29)			Ch. Velocity (ft/sec)			Top Width (ft)		
Flood Ret. Pd.	Flow Rate (cfs)	Modified Existing	Proposed	Change	Modified Existing	Proposed	Change	Modified Existing	Proposed	Change
1-year	1650	5.7	4.5	-1.2	1.7	2.7	1	664.1	142.5	-521.6
2-year	3600	8.3	7.4	-0.9	1.8	2.3	0.5	780.1	758.8	-21.3
5-year	6000	10.5	9.9	-0.6	2.1	2.3	0.2	828.8	830	1.2
10-year	7900	11.4	11	-0.4	2.2	2.5	0.3	1713.9	1690.1	-23.8
25-year	10800	12.7	12	-0.7	2.4	3	0.6	1807.7	1744.9	-62.8
50-year	13200	13.4	13.1	-0.3	2.7	3.1	0.4	1870.8	1853.2	-17.6
100-year	16000	14.5	13.7	-0.8	2.8	3.4	0.6	1901.8	1878.7	-23.1
200-year	19000	15.7	15.2	-0.5	2.9	3.3	0.4	1942.2	1920.3	-21.9
500-year	24000	18	17.5	-0.5	2.9	3.3	0.4	2162.1	2124.4	-37.7

XS 1.60	Storm	WSEL (ft, NGVD-29)			Ch. Velocity (ft/sec)			Top Width (ft)		
Flood Ret. Pd.	Flow Rate (cfs)	Modified Existing	Proposed	Change	Modified Existing	Proposed	Change	Modified Existing	Proposed	Change
1-year	1650	5.9	4.8	-1.1	2.5	3.2	0.7	357.38	242.42	-114.96
2-year	3600	8.4	7.5	-0.9	1.8	4.1	2.3	1513.12	684.38	-828.74
5-year	6000	10.6	10	-0.6	1.5	2.2	0.7	1929.3	1879.8	-49.5
10-year	7900	11.5	11.1	-0.4	1.6	2.1	0.5	2065.7	2040.9	-24.8
25-year	10800	12.7	12.2	-0.5	1.7	2.4	0.7	2109.6	2088.5	-21.1
50-year	13200	13.6	13.2	-0.4	1.8	2.4	0.6	2134.3	2124.1	-10.2
100-year	16000	14.7	13.9	-0.8	1.9	2.6	0.7	2171.6	2145.1	-26.5
200-year	19000	15.9	15.4	-0.5	1.9	2.5	0.6	2210.9	2194.5	-16.4
500-year	24000	18.1	17.6	-0.5	1.8	2.5	0.7	2294.1	2272.3	-21.8

Table 1